Health Consultation

Public Health Evaluation of Arsenic and Cadmium Levels
in Air and Residential Soils

HERCULANEUM LEAD SMELTER SITE

HERCULANEUM, JEFFERSON COUNTY, MISSOURI

EPA FACILITY ID: MOD006266373

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by

Missouri Department of Health and Senior Services
Section for Environmental Public Health
Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Statement of Issues and Background

Statement of Issues

The Missouri Department of Health and Senior Services (DHSS) and the Agency for Toxic Substances and Disease Registry (ATSDR) were asked by Herculaneum community members if arsenic and cadmium levels found in the air and in residential and school soils in the Herculaneum community could lead to adverse health effects. This health consultation responds to that request. This health consultation will assess exposure to levels of cadmium and arsenic found in sampling conducted since the fall of 2001.

Background

The Herculaneum lead smelter is an active facility that has been in operation in this community since 1892. The Doe Run Company currently owns and operates the smelter. The facility is located at 881 Main Street in Herculaneum, Missouri, approximately 25 miles south of St. Louis, Missouri, on the Mississippi River. A lead ore concentrate, consisting of approximately 80% lead sulfide, is processed at the smelter. The ore is transported by truck from eight lead mines operated by the company near Viburnum, Missouri, approximately 75 miles south-southwest of Herculaneum. The 52-acre Herculaneum facility consists of a smelter plant, a 24-acre waste slag storage pile, and an on-site sulfuric acid plant (1). Figures 1 and 2 display the location of the smelter and air monitors in the community (2).

Environmental sampling has shown lead contamination throughout the community and high prevalence rates of elevated blood lead levels in children less than 72 months of age (3). Several exposure reduction activities have been implemented including smelter emission and fugitive dust reductions, soil yard replacements, and in-house dust removals (4).

The community has also expressed concern about arsenic and cadmium emissions from the smelter and its associated operations (including emissions from trucks hauling ore into the smelter). Specifically, the community is concerned about past and current arsenic and cadmium emissions from the smelter and if combined (past and continuing) exposures could result in adverse health effects. In particular, concerns have been raised about adverse effects on the kidney. In addition, the community has asked questions about the potential for exposures via ingestion of contaminated home-grown fruits and vegetables.

The U. S. Environmental Protection Agency (EPA) sampling of surface soil in residential yards and school properties in Herculaneum has found levels of arsenic ranging from 1.5 parts per million (ppm) to 82 ppm and cadmium levels ranging from 0.52 ppm to 240 ppm (5). Some of these yards/properties have been previously remediated. These concentrations were from a multi-aliquot sample (residential yards are divided into quadrants and nine randomly collected aliquots are combined into one composite sample from each quadrant; these quadrant composite samples were

analyzed for lead using a x-ray fluorescence analyzer with approximately 10% randomly chosen and sent to a laboratory for confirmation; in addition to lead this 10% portion of the total sample was also laboratory analyzed for other metals including arsenic and cadmium). The highest arsenic and cadmium levels found were from the same residential yard west of the smelter (the house that was on this yard has been razed). Arsenic and cadmium have also been found on street dust samples at levels up to 138 ppm and 598 ppm, respectively (6).

Samples were collected and analyzed according to a Quality Assurance Project Plan (QAPP) developed and approved by EPA. EPA attempted to obtain access to all properties east of Hwy. 61. As access was gained, sampling was conducted on residential yards and public properties. According to EPA, only a few properties did not give access. Therefore, these data are considered representative of the current contamination in the area east of Hwy. 61 (the area most affected by the smelter) and to be of high quality, per the EPA QAPP.

Since October 16, 2001, air monitoring conducted by EPA in the community has found arsenic levels up to 0.64 micrograms per cubic meter of air ($\mu g/m^3$) (November 26, 2001) and cadmium levels up to 0.66 $\mu g/m^3$ (April 7, 2002), respectively. At these same sample locations, lead has been found up to 65 ug/m^3 (November 26, 2001) (7). These were samples taken over a 24-hour period (8). The highest levels of all of these metals were found in the same residential area, although not all on the same day. Interestingly, cadmium concentrations were non-detect at this sampling point on the date that the 0.64 $\mu g/m^3$ arsenic and 65 ug/m^3 lead were detected. Similarly, arsenic concentrations were non-detect at this sampling point on the date that the 0.66 $\mu g/m^3$ cadmium and 6.4 ug/m^3 lead were detected (7). While the Missouri Department of Natural Resources (DNR) has taken air samples to assess the smelter's compliance with air regulations, the community had expressed concern that these samples may not be representative of some of the highest current emissions from the smelter. Therefore, EPA purposefully took these samples on days in which DNR was not conducting compliance sampling. Normally, these samples were taken every 2-4 days (8). EPA conducted sampling at four monitors located in the community along haul routes for a total of approximately 56 samples per monitor. Monitors were to the south, north and west (no monitors were to the east since the site is bounded by the Mississippi River). A total of 224 samples were taken from the four monitors from October 13, 2001- April 10, 2002. Samples were collected as part of the EPA Site Characterization QAPP and according to EPA Region 7 Standard Operating Procedures 2314.1A and 2314.2A. Therefore, these samples are considered representative of current air concentrations in the community affected by the smelter.

Except for the first day of sampling (October 13, 2001), the minimum detection limits are between 0.25-0.26 ug/m^3. On October 13, detection limits were much lower. Results of sampling detected arsenic, cadmium, and lead at least one time at each of the four EPA monitors. Arsenic was detected four times (0.001 - 0.64 $\mu g/m^3$); cadmium was detected 12 times (0.001 - 0.66 ug/m^3); and lead was detected on almost every sample date (0.18 – 65 ug/m^3). All of the cadmium and arsenic detections were from the same monitor location (Location F8 – see Figure 1) (7).

It is important to note that the air monitoring conducted over the past year is yielding lower airborne lead levels than in previous years; therefore, it is likely that the levels of arsenic and cadmium are

also lower than they were prior to additional emission controls being put in place. DHSS could find no data on airborne arsenic and cadmium levels prior to October 13, 2001.

In April – June 2002, EPA conducted indoor dust vacuum and wipe sampling at homes which have had interior clean-ups performed. Approximately 3 months after the cleaning was completed, sampling has found dust arsenic and cadmium concentrations up to 39 and 24.2 ppm, respectively. Additionally, dust arsenic and cadmium loading values were as high as 0.817 and 0.2 milligrams per square foot (mg/ft^2), respectively Lead was detected in all of the vacuum and wipe samples. Post-remediation indoor vacuum samples detected lead from 290 to 3,300 ppm; surface wipe samples found lead from 0.01 – 43 mg/ft^2. (9).

Discussion

Completed pathways of exposure to cadmium and arsenic (along with lead) in Herculaneum are expected to be incidental ingestion of soil and inhalation of air and dust for the past and present, with the potential for similar exposure pathways to be present in the future. While cadmium and arsenic are also present in settled road dust, direct exposure to these two metals from road dust is not likely to be frequent enough to warrant health concern. However, concern has been expressed that the metal contaminants could become airborne, could migrate off streets into residential yards, and could result in exposures harmful to health. Thus, air and residential and school soil sampling results are evaluated in this health consultation. First, exposures and possible health effects to arsenic and cadmium will be evaluated separately. Then, a general evaluation of the possible health effects resulting from exposures to metals that have the same target organ (e.g., lung, kidney) is presented.

Air sampling results evaluated in this health consultation are reflective of current exposures. Recently, there has been significant activity by Doe Run to decrease air emissions from the facility. Therefore, exposure levels to past emissions, and subsequent health implications cannot be determined, based on currently available data.

The EPA recontamination sampling demonstrates that residential interiors offer another exposure source to arsenic and cadmium. This would involve inhalation and incidental ingestion of contaminated dust. Since data for past/pre-remediation interior dust arsenic and cadmium levels are not available, this exposure pathway was not specifically evaluated in this consult; other than to consider that it could be assumed to have contributed to past exposures and accumulated body burden.

Arsenic
Current Exposure

Soil: The highest level of arsenic found in the laboratory-analyzed Herculaneum residential soils is 82 ppm. This value was compared to environmental media evaluation guidelines (EMEGs) developed by ATSDR. EMEGs are media-specific comparison values used to select chemical contaminants of potential concern (10). However, the presence of a contaminant at levels greater than the EMEG does not necessarily mean adverse health effects will result from exposure to this contaminant. Instead, it is an indication that exposure to this contaminant in a particular medium (e.g., soil, air) needs to be investigated further. The soil EMEG for chronic exposure (365 days or more) to arsenic is 200 ppm for adults and 20 ppm for children (11). Because the highest level found in Herculaneum is greater than the EMEG for children, soil arsenic exposure was evaluated further.

A daily dose of arsenic from soil for both an adult and a child were calculated. These calculations were completed using the highest current residential arsenic level, and an assumption of 50% bioavailability (14). This scenario represents the level of exposure that can reasonably be expected to occur. Actual exposures should be much less. The dose calculations are presented in Appendix 1. A daily dosage of 0.00006 milligrams per kilogram per day (mg/kg/day) and 0.0005 were calculated for an adult and a child, respectively.

The daily dosages were compared to ATSDR's minimal risk levels (MRLs) for arsenic. An MRL is an estimate of daily human exposure to a substance that is likely to be without an appreciable risk of noncarcinogenic adverse health effects over a specified duration of exposure (10). As with an EMEG, a contaminant dose greater than the MRL does not necessarily mean adverse health effects are likely; instead, the MRL is used as a screening tool to determine if there needs to be further evaluation of whether this contaminant might cause adverse health effects at this site. The chronic oral MRL for arsenic is 0.0003 mg/kg/day and the acute oral MRL is 0.005 mg/kg/day (12). Since the estimated daily dosage for adults is below the MRL, so non-cancer effects are not likely. The calculated dose for children approaches the MRL. However, it is unlikely that a child would be consistently exposed to the highest level in soil. It is more probable that a child would be exposed to a lower, average concentration, therefore, adverse non-cancer effects are not expected to result from incidental soil ingestion at this site.

Soil arsenic levels were further evaluated for cancer-causing effects (skin and liver). Initially, soil concentrations were compared to a cancer risk evaluation guide (CREG) for 1×10^{-6} excess cancer risk. A CREG is a media-specific contaminant concentration derived from the chronic dose of the substance that corresponds to a maximum risk level of one excess cancer in a million people exposed over a 70-year lifetime (13). Exposure to contaminant concentrations greater than the CREG does not mean that people will develop health problems, but that further investigation needs to be done on this contaminant. The CREG for soil arsenic is 0.5 ppm (11). Since the highest soil arsenic level (82 ppm) exceeds the CREG, further calculations of the theoretical increased cancer risk were conducted.

The dosages derived in Appendix 1 were multiplied by the cancer slope factor (see Appendix 1).

The cancer slope factor estimates the excess upper-bound lifetime probability of an individual developing cancer from an exposure (13). These calculations indicated no significant increased risk of cancer from daily exposure to the highest current soil arsenic concentration for a 70-year exposure period.

Studies examining the risk of cancer from ingestion of arsenic have predominantly focused on ingestion of arsenic contaminated drinking water. Only one study was located which examined releases of arsenic from a smelter. This study examined childhood cancer incidences among children born between 1961 and 1990 in Skellefta, Sweden, where a smelter released arsenic and other pollutants including lead, copper, cadmium, sulfur dioxide, and possibly other emissions such as nickel and selenium. Childhood cancer incidences among children born in the vicinity of the smelter (i.e., within 20 kilometers) and distant from the smelter (greater than 20 kilometers) were compared with expected incidences based on Swedish national statistics. There appeared to be an increased risk of childhood cancer (all types combined) among children born in the vicinity of the smelter, but the increase was not statistically significant. In addition, the role of arsenic in any finding from this study is confounded by the presence of other metals. The number of cases was very close to the expected number among children born distant from the smelter (14).

Air: The highest level of arsenic found in recent air samples from Herculaneum was 0.64 $\mu g/m^3$. There is no air EMEG for arsenic exposure. A review of the literature found that at a concentration of 0.7 $\mu g/m^3$ (16-year average concentration), a researcher suggested a greater risk of stillbirths. However, the study also indicates that this increased risk was limited to people of Hispanic descent, who, the researcher speculated, might be an especially sensitive population due to a genetic impairment in folate metabolism (15). In addition, the ATSDR Toxicological Profile indicates this study had several limitations (e.g., small numbers of cases and controls in the high exposure group, lack of data on smoking, potential confounding exposures to other chemicals from the factory, and failure to take into account previous years of deposition in the exposure estimates) (14), making its relevance to the Herculaneum community very low. The highest air arsenic level measured in Herculaneum is slightly less than the average annual level seen in this study over a 16-year period, resulting in a much greater exposure than what has been seen in Herculaneum. Since this was the only study that found a potential adverse effect at air arsenic levels approaching the highest level seen in Herculaneum since October 16, 2001, we would not expect adverse noncancerous health effects to occur from exposure to current levels of arsenic in air.

Air arsenic levels were further evaluated for cancer-causing effects. Inorganic arsenic is classified as a human carcinogen via the inhalation route (lung cancer and possibly skin, kidney, and liver cancer). Air concentrations were compared to the CREG for arsenic (0.0002 $\mu g/m^3$) (16). Since the highest air arsenic level (0.64 $\mu g/m^3$) exceeds the CREG, further calculations were conducted.

Appendix 2 contains calculations used to determine the theoretical increased risk of cancer from exposure to air arsenic. Using the highest air arsenic level found, an increased theoretical risk of cancer was found. However, this calculation assumed a daily lifetime of exposure at this level.

Given the 2001 air data set, the maximum air concentration of arsenic is not representative of average or normal exposures. Therefore, the cancer risk calculation is very conservative, and tends to overestimate the current risk. Given this information, we would not expect an increased cancer risk due to the usual current arsenic levels found in Herculaneum.

Past Exposure

Air: Because emissions from the facility are being reduced, the air lead levels have decreased within the last several years. Therefore, it is likely that air levels of arsenic were higher in the past. Due to a lack of data, it is not possible to accurately determine whether past exposures, combined with current exposures could result in potential adverse health effects. Numerous occupational epidemiology studies of smelter operations have shown higher than expected respiratory cancer mortalities associated with arsenic exposures. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) is based on arsenic air data that associated a mean arsenic air concentration of 0.2 mg/m^3 (or 200 ug/m^3) to a significant risk of increased lung cancer. Adding an additional safety factor, the TLV of 0.01 mg/m^3 (or 10 ug/m^3) was derived for inorganic arsenic (17). It should be noted that occupational exposure guidelines are based on a 40-hour work week over a working lifetime (usually estimated to be 40 years).

Cadmium

Current Exposure

Soil: Currently, the highest level of cadmium found in residential soils is 240 ppm. The soil EMEG for chronic exposure to cadmium is 100 ppm for adults and 10 ppm for children (11). Because the highest level found in Herculaneum soils is greater than both the adult and the child EMEGs, we evaluated soil cadmium exposure further.

A daily dose of cadmium from soil for both an adult and a child were calculated. These calculations were completed using the highest residential current cadmium level and 25% bioavailability (18). This represents the level of exposure that might reasonably occur. Actual exposures should be much less. The dose calculations are presented in Appendix 3. Daily dosages of 0.00009 milligrams per kilogram per day (mg/kg/day) and 0.00075 mg/kg/day were calculated for an adult and a child, respectively.

The daily dosages were compared to MRLs for cadmium. The chronic oral MRL for cadmium is 0.0002 mg/kg/day (12). Because the daily dosages for a child is greater than the MRL, further analysis was conducted.

In people who had a lifetime of exposure through ingesting cadmium-contaminated food, a daily dose of 0.0021 mg/kg/day was found to be the threshold above which kidney effects were seen. Below this level no health effects were observed (18). The calculated dose for a child is well below the effect level reported in the study. Additionally, most concentrations are significantly (an order of magnitude) less than the concentration used in the dose calculations. It is unlikely

that a person would consistently be exposed to the maximum level detected in the environment, making our assumptions conservative. Based on our review, adverse noncancer health effects would not be expected to occur in adults or children due to exposure to current soil cadmium through ingestion. However, if past exposures were higher, and we consider potential accumulated body burden along with continued exposures, we cannot rule out possible noncancer health effects.

In a repeated surveillance study comparing children living near a lead smelter with those in a rural area and an urban area, urine cadmium was found to be elevated in those residing less than 1 kilometer from the lead smelter. Soil cadmium levels ranged from 11 to 102 ppm near the smelter (19). These soil values are within the range of values seen around the Herculaneum site.

Studies of humans or animals that ingest cadmium have not found increases in cancer (16); therefore, we would not expect exposures from ingestion of cadmium in Herculaneum to cause cancer.

Air: The highest level of cadmium found in air samples from Herculaneum is 0.66 $\mu g/m^3$. There is no air EMEG for cadmium exposure. A review of the literature found that in a group of people exposed to air concentrations of 37.9 $\mu g/m^3$ for 21 years, kidney problems were observed. However, in this same group, no effects were seen at a concentration of 15.3 $\mu g/m^3$ (18). In the repeated surveillance study mentioned above, the mean air cadmium value from samples collected less than 1 kilometer from the lead smelter was 0.09 ug/m^3.(19). The ACGIH occupational exposure guideline for cadmium of 10 ug/m^3 (cadmium, total particulates) is set to minimize the potential for development of preclinical kidney dysfunction (urinary β-microglobulin excretion). Although adverse noncancerous health effects are not expected based on current levels of cadmium in air, accumulated doses from past emissions along with continued exposures may result in adverse impacts on kidney function.

It should be noted that cigarette smoking has been shown to increase levels of cadmium in the body (18).

Air cadmium levels were also evaluated for cancer-causing effects. Cadmium is classified as a suspected human carcinogen via the inhalation route (lung cancer). The ACGIH occupational exposure guideline for cadmium of 2 $\mu g/m^3$ (cadmium, respirable particles) is intended to reduce cadmium accumulation in the lung which could induce lung cancer. Air concentrations were compared to the CREG for air cadmium (0.0006 $\mu g/m^3$) (16). Since the highest air cadmium level (0.66 $\mu g/m^3$) exceeds the CREG and approaches the ACGIH occupational exposure guideline, further calculations were conducted.

Appendix 4 contains calculations used to determine the theoretical increased risk of cancer from exposure to air cadmium. Using the highest current air cadmium level, an increased theoretical risk of cancer was found. However, this calculation assumed a lifetime of exposure at this level. Given the 2001 air data set, the maximum air concentration of cadmium is not representative of average or normal exposures. Therefore, the cancer risk calculation is very conservative, and tends to overestimate the current risk. Given this information, we would not expect an increased

cancer risk due to the usual current cadmium levels found in Herculaneum.

Past Exposure

As presented in the arsenic discussion, because emissions from the facility are being reduced, the air lead levels have decreased within the last several years. Therefore, it is likely that air levels of cadmium were higher in the past. Due to a lack of data, it is not possible to accurately determine whether past exposures, combined with current exposures could result in body burdens that may increase the potential for adverse health effects.

Current Exposure

Vegetables: Accumulation of metals due to atmospheric deposition has been documented for lead and cadmium. Vegetables grown in cadmium-contaminated soils have been found to uptake cadmium more efficiently than other trace metals (20). The most recent minimum and maximum air and soil contaminant concentrations from Herculaneum were input into the linear regression formula developed by Vousta et al (20) . This regression formula allows an approximation of contaminant values that might be found in vegetable leaves and roots at Herculaneum. Results of these calculations are displayed in Table 1.

Table 1. Estimated metal contaminant levels in vegetables[1] (20)

Metal	Vegetable leaf concentration	Vegetable Root concentration
Cadmium[2]	<7.8 – 24	0.79 – 365
Arsenic[3]	<1.6 – 4.3	0.0003- 0.098
Lead[4]	Up to 5	Up to 2.7

[1] Contaminant concentrations in ppm
[2] air values, <0.24-0.66 ug/m^3, soil values 0.52-240 ppm
[3] air values, <0.24-0.64 ug/m^3, soil values 1.5-82 ppm
[4] air values up to 64 ug/m^3 , soil values up to 2,000 ppm

In another study, levels of cadmium in 612 residential soil samples collected near zinc smelters ranged from 0.4 to 70.5 ppm (geometric mean of 4.9 ppm). Vegetable samples from residential gardens in these areas found cadmium levels in celery from 0.6 to 11.8 ppm (geometric mean of 2.4 ppm) (21). Results of a forested area near a copper smelter in another study found elevated levels of cadmium in edible mushrooms. Soil cadmium levels ranged from 0.25 to 10 ppm. Cadmium levels in mushrooms varied by species and ranged from 0.75 to 16.5 ppm (22). The upper range of cadmium levels found in Herculaneum soils is higher than the latter two studies. Insufficient information exists to predict the levels of cadmium in garden vegetables in the Herculaneum area. However, data do show that cadmium may be uptaken to levels that may contribute significantly to exposures. Thus, area-specific data are needed to assess the potential exposures from ingestion of area garden vegetables.

Effects of metals on the kidney: Exposures to lead that result in blood lead levels above 10 µg/dl in children have been suggested to have a slight impact on proximal tubule (part of the kidney) function. One study of children found a significant difference in retinal-binding protein (a sensitive indicator of kidney dysfunction) levels in urine from children residing near a lead smelter compared to a control group (23). Another study found a relationship between blood lead levels and urine N-acetyl-α-D-glucosaminidase (NAG, another sensitive indicator of renal effects) in children residing near a lead smelter (24). Exposures to other metals may have contributed to these findings. Occupational exposures to lead have been associated with renal effects (25).

Environmental sampling has shown lead contamination throughout the community. For example, lead has been found in yard soils at concentrations up to 33,100 parts per million (ppm) (26); in air ranging from non-detectable (ND) to 85 micrograms per cubic meter ($\mu g/m^3$) (27); and in dust on streets ranging from 30,000 ppm to 300,000 ppm (28).

Like lead, occupational exposures to cadmium have been shown to impact adult renal function (29). No studies of urine cadmium and renal function biomarkers in children were found in the literature.

Arsenic is not associated with adverse noncancer impacts on renal function. However, data suggests that ingestion of high doses may be related to increased kidney and bladder cancer (14). Levels of arsenic found in the residential soils tested are not high enough to result in elevated exposures via ingestion. Since the kidney is a target organ for arsenic, exposures to even low levels may contribute to renal function changes caused by cadmium.

Child Health Initiative and Susceptible Subpopulations

Some people exhibit enhanced responses to chemical exposures compared to the majority of people exposed to the same contaminant level. Reasons might include genetic makeup, age, health and nutritional status, and exposure to other toxic substances (e.g., cigarette smoke).

Populations with depleted stores of calcium, iron, or other dietary components due to multiple pregnancies and/or dietary deficiencies could have increased cadmium absorption through ingestion. As mentioned earlier, some animal studies have shown that the bones of young animals are more susceptible to damage. Infants and children might also have a higher rate of gastrointestinal absorption of cadmium, and their bones might be more susceptible to damage (18).

Populations with kidney damage from causes other than cadmium exposure (e.g., diabetes, some drugs and chemicals, natural age-related decline in kidney function) might exhibit further kidney damage at lower levels of exposure than would be observed in normal, healthy adults (18).

Results of these studies may have been confounded by the presence of metals other than the metal under study.

Children's doses were calculated for arsenic exposures at this site. Children do not appear to be at an increased risk for adverse health effects due to current arsenic exposure at this site. No studies were located regarding unusual susceptibility of any human subpopulation to arsenic (14). Exposure to only cadmium and possibly arsenic at the levels currently found at the site (without the presence of lead) may not result in renal function changes. Children with exposures to lead may be more susceptible to renal function changes. Compared to adults, young children ingest and inhale more lead per unit body weight than adults. Also children are more likely than adults to inadvertently ingest lead-contaminated soil during play and hand-to-mouth behaviors. Finally, because changes in the kidney size relative to its percent of body weight, renal glomerular filtration rate, and basal metabolic rate change from infancy through adolescence, the adverse effects of metals on kidney function for these ages may be more likely than for adults (30).

Conclusions

Given the calculated exposure doses (using conservative exposure assumptions) and the research literature on cadmium and arsenic toxicity, it seems highly unlikely that adverse health effects would be observed from current exposures to current air and soil arsenic and cadmium levels. Because some arsenic and cadmium exposure due to the incidental ingestion of residential and school soil and inhalation of air and dust contaminated with cadmium and arsenic in Herculaneum is still possible, although at levels not expected to be harmful, this site is classified as a no apparent public health hazard for current exposure to arsenic and cadmium.

In addition, as long as these levels do not increase, they would remain a no apparent public health hazard in the future.

With regards to past exposures, a data gap exists for air and dust arsenic and cadmium levels in past years. This may have resulted in cumulative exposures that, along with continued exposures to current levels, may result in the potential for adverse health effects. It is likely that air levels of arsenic and cadmium were higher in the past; however, due to a lack of data, it is not possible to accurately determine whether past exposures to arsenic and cadmium in air and/or soil were at levels of health concern. Thus, past exposures to arsenic and cadmium are classified as an indeterminate public health hazard. This indeterminate public health hazard applies to individuals exposed just in the past as well as those exposed in the past and having continuing, although lower, exposures.

Insufficient site-specific data regarding the uptake of cadmium and other metals by garden vegetables classifies exposures to these metals from garden vegetables as an indeterminate public health hazard.

Recommendations

Consider conducting an Exposure Investigation to fill data gaps regarding: 1) past exposures to cadmium, and 2) determine if locally-grown vegetables are safe for consumption.

Although current arsenic levels do not pose a health hazard, residents have expressed concern about their current exposure to arsenic. Therefore, concurrent with the proposed Exposure Investigation, consider providing urine arsenic testing as a public health service to the community. This effort would assist in alleviating concerns and further reinforce that current arsenic levels do not pose a hazard.

Analyze air sample filters from earlier sampling periods for arsenic and cadmium to determine if current data are representative of past levels.

Public Health Action Plan

The Public Health Action Plan (PHAP) for the Herculaneum Lead Smelter site contains a description of actions to be taken by the Missouri Department of Health and Senior Services (DHSS), the Agency for Toxic Substances and Disease Registry (ATSDR), and other involved parties. The purpose of the PHAP is to ensure that this health consultation not only identifies public health hazards, but provides an action plan to mitigate and prevent adverse human health effects resulting from past, present, and future exposures to contamination from the site. Included is a commitment from DHSS, ATSDR, or both to follow up on this plan to ensure that it is implemented.

1. DHSS/ATSDR will cooperate with the U.S. Environmental Protection Agency (EPA) and the Missouri Department of Natural Resources (DNR) to assure that exposure reduction activities at this site (e.g., plant emission controls, yard replacements, interior residential dust removals, etc.) will continue, and be maintained at a level that assures protection of public health. This includes reviewing and commenting on future remedial plans and recontamination studies.

2. DHSS/ATSDR will review any additional data that becomes available regarding arsenic and cadmium contamination in Herculaneum to determine public health implications.

3. DHSS/ATSDR will pursue conducting an Exposure Investigation involving biological and vegetable sampling for arsenic and cadmium.

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Attachments: Figure 1 - Site Map
Figure 2 - Site Map
Appendix 1 - Calculation of Soil Arsenic Ingestion Doses
Appendix 2 - Calculation of Air Arsenic Inhalation Doses
Appendix 3 - Calculation of Soil Cadmium Ingestion Doses
Appendix 4 - Calculation of Air Cadmium Inhalation Doses

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Certification

The Missouri Department of Health and Senior Services prepared this health consultation for the Herculaneum Lead Smelter Site, Public Health Evaluation of Arsenic and Cadmium Levels in Air and Residential Soils, under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures at the time the health consultation was initiated.

Technical Project Officer, SPS, SSAB, DHAC

The Division of Health Assessment and Consultation (DHAC), ATSDR, has reviewed this health consultation and concurs with its findings.

Branch Chief, SSAB, DHAC, ATSDR

Appendix 1
Calculation of Soil Arsenic Ingestion Doses

Adult Dose:

$$ID_s = \frac{C\ (\%\ \text{absorbed}) \times IR \times EF \times 10^{-6}}{BW}$$

Where: ID_s = soil ingestion exposure dose (mg/kg/day)
C = contaminant concentration (mg/kg)
% absorbed = absorption rate (as a decimal)
IR = soil ingestion rate (100 mg/day for adult, 200 mg/day for child)
EF = exposure factor (unitless)
BW = body weight (70 kg for adult, 16 kg for child)

$$ID_s = \frac{82 \times .50 \times 100 \times 1 \times 10^{-6}}{70}$$
$$= .00006 \text{ mg/kg/day}$$

Child Dose:

$$ID_s = \frac{82 \times .5 \times 200 \times 1 \times 10^{-6}}{16}$$
$$= .0005 \text{ mg/kg/day}$$

Cancer Risk:

Risk = Cancer Slope Factor $(\text{mg/kg/day})^{-1}$ x dose (mg/kg/day)

= 1.5 x .00012
= 0.00018

*** =** These calculations are designed and use assumptions to represent a maximum worst case scenario for exposure; actual exposure would most likely be less.

Appendix 2

Calculation of Air Arsenic Inhalation Doses

Adult Dose:

$$ID_a = \frac{C \times IR \times EF}{BW}$$

Where:
ID_a = inhalation exposure dose (mg/kg/day)
C = contaminant concentration (mg/m^3)
IR = inhalation rate (23 m^3/day)
EF = exposure factor (unitless)
BW = body weight (70 kg for adult)

$$ID_a = \frac{0.00064 \times 23 \times 1}{70}$$

= .00021 mg/kg/day*

Cancer Risk:

Inhalation Unit Risk = .0043 $(\mu g/m^3)^{-1}$

Risk = Inhalation Unit Risk x Concentration

= .0043 x .64
= .0027

*** =** These calculations are designed and use assumptions to represent a maximum worst case scenario for exposure; actual exposure would most likely be less.

Appendix 3
Calculation of Soil Cadmium Ingestion Doses

Adult Dose:

$$ID_s = \frac{C\ (\%\ absorbed)\ x\ IR\ x\ EF\ x\ 10^{-6}}{BW}$$

Where: ID_s = soil ingestion exposure dose (mg/kg/day)
C = contaminant concentration (mg/kg)
% absorbed = absorption rate (as a decimal)
IR = soil ingestion rate (100 mg/day for adult, 200 mg/day for child)
EF = exposure factor (unitless)
BW = body weight (70 kg for adult, 16 kg for child)

$$ID_s = \frac{240\ x\ .25\ x\ 100\ x\ 1\ x\ 10^{-6}}{70}$$

= .00009 mg/kg/day*

Child Dose:

$$ID_s = \frac{240\ x\ .25\ x\ 200\ x\ 10^{-6}}{16}$$

= .00075 mg/kg/day*

*** =** These calculations are designed and use assumptions to represent a maximum worst case scenario for exposure; actual exposure would most likely be less.

Appendix 4

Calculation of Air Cadmium Inhalation Doses

Adult Dose:

$$ID_a = \frac{C \times IR \times EF}{BW}$$

Where: ID_a = inhalation exposure dose (mg/kg/day)
C = contaminant concentration (mg/m^3)
IR = inhalation rate (23 m^3/day)
EF = exposure factor (unitless)
BW = body weight (70 kg for adult)

$$ID_a = \frac{0.00066 \times 23 \times 1}{70}$$

= .00022 mg/kg/day*

Cancer Risk:

Inhalation Unit Risk = .0018 $(\mu g/m^3)^{-1}$

Risk = Inhalation Unit Risk x Concentration

= .0018 x .66
= .0012

*** =** These calculations are designed and use assumptions to represent a maximum worst case scenario for exposure; actual exposure would most likely be less.

Figure 1

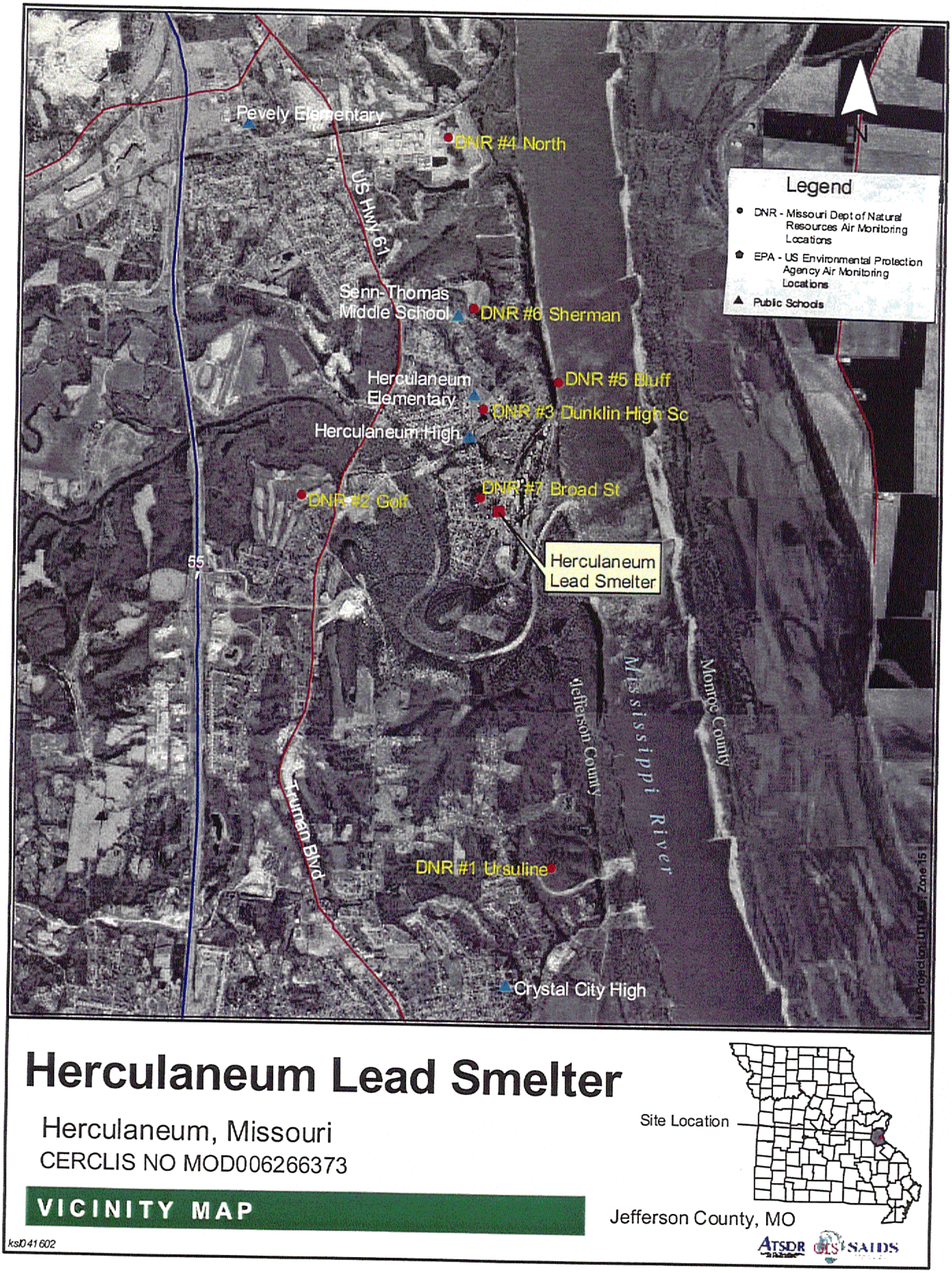
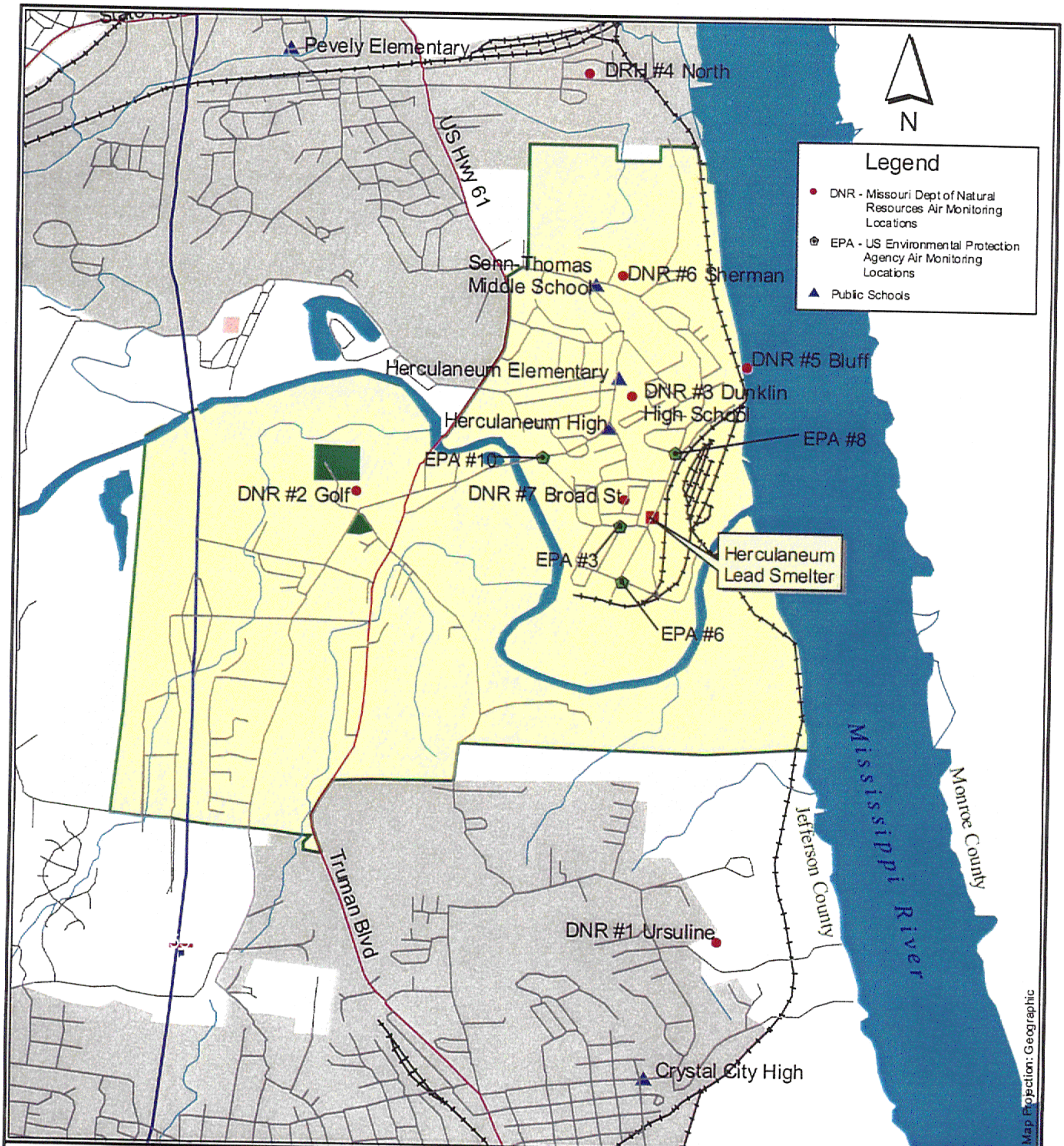

Pevely Elementary
DNR #4 North
US Hwy 61
Senn-Thomas Middle School
DNR #6 Sherman
Herculaneum Elementary
DNR #5 Bluff
DNR #3 Dunklin High Sc
Herculaneum High
DNR #7 Broad St
DNR #2 Golf
Herculaneum Lead Smelter
55
Jefferson County
Mississippi River
Monroe County
Truman Blvd
DNR #1 Ursuline
Crystal City High
N
Legend
DNR - Missouri Dept of Natural Resources Air Monitoring Locations
EPA - US Environmental Protection Agency Air Monitoring Locations
Public Schools
Herculaneum Lead Smelter
Herculaneum, Missouri
CERCLIS NO MOD006266373
VICINITY MAP
Site Location
Jefferson County, MO
ksl041602
ATSDR
SAIDS

Figure 2



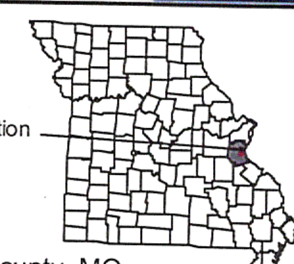
Herculaneum Lead Smelter

Herculaneum, Missouri

CERCLIS NO MOD006266373

VICINITY MAP

ksl041602



Jefferson County, MO